2014 International Symposium on Extreme Ultraviolet Lithography October 27-29, 2014 Washington, D.C.

Development of Microwave Discharged Produced Plasma for EUV source

Saya TASHIMA [1)] , Masami OHNISHI [1)] , Waheed HUGRASS [2)] , Hodaka OSAWA [1)] , Keita Sugimoto [1)]
1) Department of Electrical and Electronic Engineering, Faculty of Engineering Science, Kansai University,
2) School of Computing and Information Systems, University of Tasmania

Abstract & Introduction

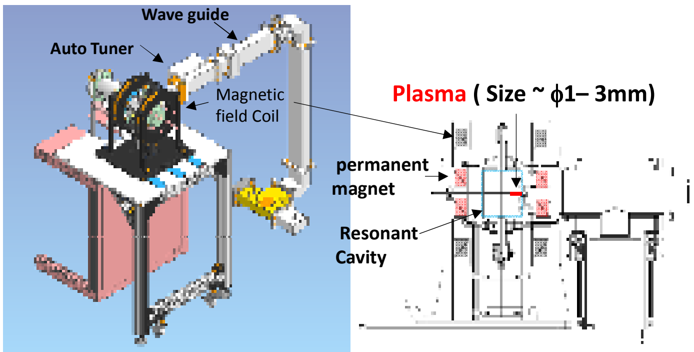
•EUV lithography is a leading technology for the production of the next-generation. But there are still several problems to be resolved including the development of suitable EUV light sources.
•The 13.5-nm EUV radiation is obtained from plasma by DPP and LPP sources mainly.

However,
1) The debris cause contamination of the EUV mirrors and the silicon wafers.
2) The further increases of the EUV output power is required.

• **The microwave discharge produced plasma (MDPP) source does not produce debris at least in principle.**
Because it is electrode-less. Xenon is used as the working gas although it has a lower conversion efficiency compared to tin because it does not produce much contamination.
•**The duration of the EUV produced by the MDDP is longer than LPP sources.**
When the frequency of EUV output is same, the required peak radiation power is much lower

The experimental facility and the EUV measurement system are described and some preliminary experimental results are presented.

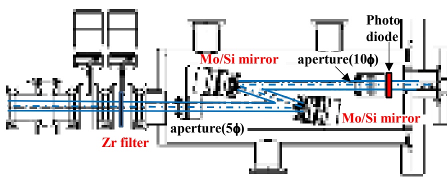
Microwave discharged produce plasma system



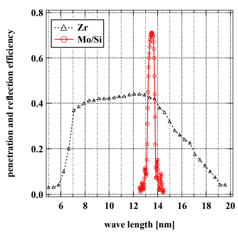
The cylindrical cavity mode ; TE111 and TM010

Produce plasma;
1) The 2.45 GHz microwave is injected to cavity and penetrated to wall quartz tube.
2) The Xenon gas is ionized in the quartz tube by Jules heating of microwave electron field.

EUV measurement system



The reflection meter system, which consists of a Zr filter, two Mo/Si multi-layer reflection mirrors, apertures of ϕ5 and ϕ10, and a photo diode.



The reflectivity of the Mo/Si mirror and the transmission of the 100 nm Zr filter as functions of the wavelength.

Size of Quarts tube	TM010	TE111
3mm Closed	0.03W (0.9 Pa)	0.26 (3 Pa)
2mm Closed	0.04 W (1 Pa)	0.77 (5 Pa)
1mm Closed	0.7 W (6 Pa)	0.63 W (5.5 Pa)
3 mm Open	~ 0 W	1.1 W (5 Pa)
2mm Open	~ 0 W	0.28 W (3.5 Pa)

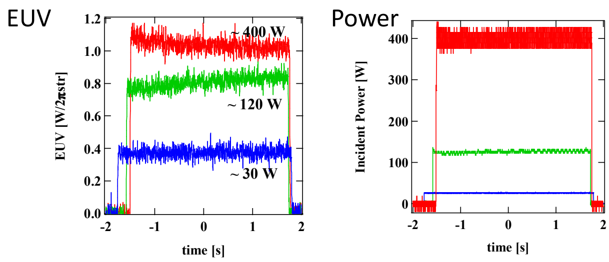
Conclusion & Future Plan

•Experimental data show EUV power was 1.1 [W/2πstr] at CW operation
•The EUV power (P_{EUV}) dependence on Xe Gas pressure shows optimum pressure (~ 6 Pa @1mm sized plasma).
•P_{EUV} increase with incident microwave power.

Future plane; Improvement of cooling system and inclement incident power.
The performance of the present facility is limited mainly by the incident power and the insufficient cooling system of the quart tube.

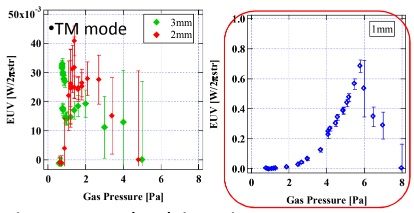
The study is supported by the START project by the Ministry of Education, Culture , Sports, Science and Technology.

Discharge Waveforms (TE mode)



•CW operation ~ 3.5 sec.

Dependence of EUV on Xe Gas pressure and incident Power



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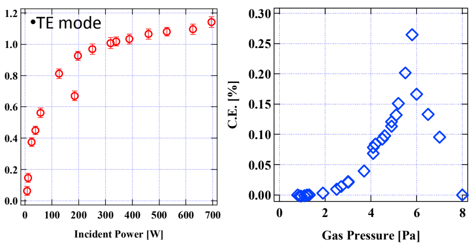
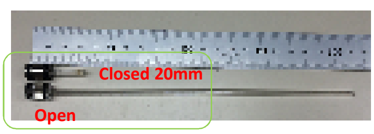
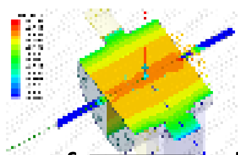


•Conversion Efficiency = P_{EUV}[W/2pstr]/P_{micro}[W]
•The C.E. ~ 0.28 % is achieved.

Quarts tube





The dependence on size of quartz tube (plasma) for TM and TE resonant cavity.